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LINER EXPANDER

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Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

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No. OF CLAIMS

LINER EXPANDER

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This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

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Since tools of the type mentioned above often are cm.ployed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

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Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

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Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the wall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the wall of the casing and effect a fluid-tight seal.

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In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 33 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 25 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential sorew element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38s, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

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Constant force spring element 37 comprises column element 43, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lover bearing plate member 46 contacts the lover ends of the columns and is moved upwardly along the shaft by longitudinal movement of lover shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lover race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lover limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

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fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such 10 as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft lo.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a 20 critical compression loading of 450 pounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein $\mathbf{P}_{\mathbf{C}}$ is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A and B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the 30 yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

approximately one inch, at which the longitudinal deflection was approximately: 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble 41 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

I CLAIM:

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1. A device for expanding a metallic liner inside a conduit which
2 device comprises a shaft element, an expanding die member attached to said
3 shaft element, said die member comprising a movable liner-forming member
4 positioned on said shaft and being radially movable in respect thereof to
5 contact said liner, an expander member slidably positioned on said shaft
6 between said shaft and said die member to move said liner-forming member
7 from said shaft, and a constant force spring member positioned on said shaft
8 to contact said expander member and to maintain said expander member against
9 said liner-forming member, whereby said liner-forming member is urged against

said liner by a substantially constant force.

- 1 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said 2 3 conduit to expand said liner: a cylindrical shaft element, an expanding die <u>lı</u> member attached to said shaft, said die member comprising a plurality of arm members disposed around said shaft and being pivotable outwardly therefrom to 5 6 contact said liner, a cone member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said 8 shaft, and a constant force spring member positioned on said shaft to contact 9 said cone member and to maintain said cone member in contact with said arm 10 members, whereby said arm members are urged outwardly by a substantially 11 constant force.
 - 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said come member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

- 4. The device of Claim 3 wherein said compression means comprises a differential screw connecting said spring member and said shaft.
- 5. The device of Claim 3 wherein said stop means comprises a sleeve-like element connected to said movable bearing plate member and slidably positioned on said shaft and a member connected to said shaft to limit the travel of said sleeve-like element.
 - 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said shaft.
 - 7. A device for installing an expanded metallic liner in a conduit which comprises a cylindrical shaft element; an expanding die member mounted on said shaft, said die member comprising a plurality of arm members disposed circumferentially around the outside of said shaft and being pivotable outwardly therefrom to contact the liner; a conical expanding member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft; a plurality of slender columns, each having a long rectangular cross-section and disposed circumferentially about said shaft; an upper bearing plate member and a lower bearing plate member, each slidably positioned on said shaft and contacting opposite ends of said columns; limiting sleeves attached to each of said bearing plate members and slidably positioned on said shaft; a shoulder member on said shaft; a differential screw element connecting said shoulder and said shaft to apply a buckling load to said columns; said shoulder being engageable with the limiting sleeve connected to said lower bearing plate member, whereby the axial travel of said bearing plate members is limited; said column members transmitting their buckling load to said arm members to urge said arm members outwardly with a substantially constant force.

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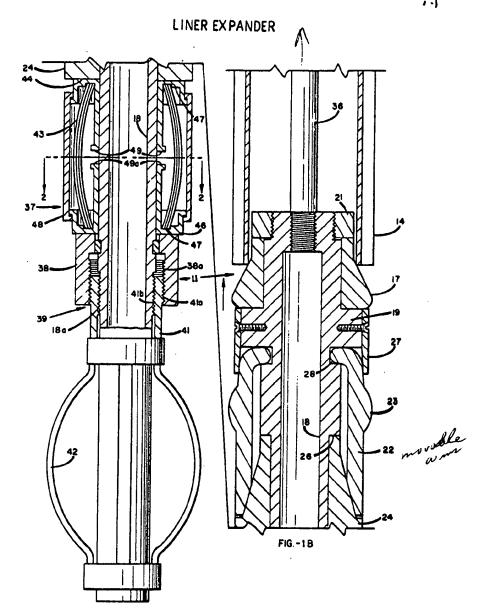
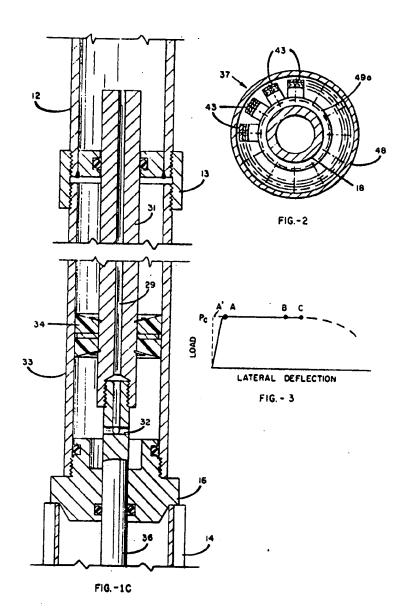


FIG.-1A



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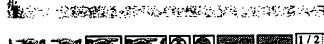
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2. A dovice for expending a metallic line; inside a cuchete which device comprises a staff almost, an expending the matter desire attached to said staff olcohomb, said die member comprising a movelle liner-forming number positioned on said shaft and saing catholic movelle in respect thorout to contact said liner, as expender morber alidably positioned on said shaft between said liner, as expender morber alidably positioned on said shaft between said shaft and said die member to move said liner-forming number from said staff, and a constant force spring number positioned on said staff, to contact said expender symbor had to maintain said expender sandor against said liner-forming member; starely said liner-forming member to unput against said liner-forming member; starely said liner-forming member to unput against said liner to a material line constant.

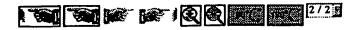
2. In a device for installing an expended metallic liner in a conduit wherein an expending die is moved through a liner positional in said souther to exceed said liner: a cylistrical staff almost, an expending die souther to exceed said liner: a cylistrical staff almost, an expending die moster attached to said shaft, said die sember comprising a plusality of arm mosters disposed around said shaft and being pivotable extearly therefore to contact said liner, a come assiste midally positioned on said shaft between said shaft and said arm mosters to tarpo said arm mosters colearedly frue said shaft, and a constant force spring number positioned on said staff to contact shaft, and a constant force spring number positioned on said staff to contact said some moster in contact with said arm mosters, phorety said some moster in contact with said arm mosters, phorety said some technically constant force.

3. The device of Claim 2 wherein said combust force spring construes a plumbility of columns disposed around said shaft, a first bearing plate number, each of said bearing plate members consisting opposite cols of said columns, at least one of said bearing plate members being movebly restricted on said shaft and being in contact with said come number, stop means commerted to said start to limit the axial traval of said moveble bearing plate number along said shaft, and compression terms for maintainers a lateral deflection to said columns.

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- . A. The device of Claim 3 wherein said compression group comprises a difformation survey commenting said spring number and said shaft.
- 5. The device of Claim 3 wherein anid shop means comprises a also re-like element commerced to said sovehip bearing plate number and missing positioned on said short and a support commuted to said shart to like the brown of said also re-like element.
- 6. The device of thata 3 wherein soil columns have a sectempolar cross-section, the width being greater than the thickness, and hering the water thus muchal to the discourt of said shart.
- 7. A device for installing at expended establis liner in a cominit which comprises a sylindrical shaft classical to accombing the system sounded on maid shalls, said the senter examining a plantity of tre sombers tippeed direnthreshielly around the outside of said shaft and budge pluotable outhims agus os expelmen arm hims has slade innerios finds hims so he store cetamotry from suid shelt; a planelity of alander columns, cash ring a long reutingular cross-section and disposed stransfermentially short aft; an upper bearing plate member and a lower tearing plate member, such slikely positioned on said shaft and contacting opposite under of said al limiting alasmon ubtended to each of stiff bearing plate numbers and alidably positioned an said statt; a shoulder number on said shaft; a nainly sures allowed; accessibly said shoulder and said state to apply sting look to said saimme; well shoulder being supposed with the limiting sizers competed to said lower bearing plate mester, whereby the arial known of said bearing plate members is limited; said column weaters bremegitting their bucking look to said any nambers to urgs said any spakers esteurolly with a substantially constant force.

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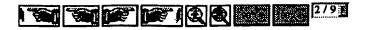
Decembers, a mained and apparatus have been developed for installing up companied assists times in on cal well or other compali. typically, a correspint about liner is immred in a conduct which is in he hired, the greatest puriphosal-dissection of the liner being slightly less then the lastes diameter of the screbalt. In expending took is persent the liner placed to the conduit, and a first-stone expending dis source a gross plantic deformation of the liner, which is expended outworldy ridou on additional firmer defendation of the limer to provide a smoo ofsigno emper or from ranti ati to whitest out no exerce foots soninct between the committeed the liner. In a typical design of this type expending tool, the frintional drug of the first-stage dis sugplies the expanding force for the account-stage die, which expanding force is a kireat function of the strength, or well thickness, of the confult is which the liner is being installed. For example, in limits oil well casing, beary es a very high Cristianal focus which results in sec ure boing required to push the expender through the limer. The application of the greet forces required sty result in rupture of the caring er in breaking the investiing tool. In tasteness whose the inherent har of the conduct is somewhat less than that anticipated, the resulta the tool to become stack in the century or otherwise age to the ensing end the tool. In other designs, such as there a quartilever agring arrengment is amployed in econortion of the the secondstrige die, verious difficulties are uncountered in obtaining a spring down larving the desired strength is continuation with the other spring. characteristics, and with the took dragging against the incide wall of the db after bring passed through the liner.

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My investion will be better understood by reference to the following description and the accompanying drawings wherein:

Piggree 1A, 18 and 1C, tabea together, convilues a partial sectional view of a preferred embediment of a liner expending tool amounting to the present investion; and



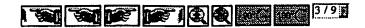


Figure 2 to a sectional when or the apparatus of Figure 1A taken at

Figure) is a typical plot of applied lock versus believison for the constant force spring device of the Lavention.

Referring to the drawings, Figure 14 is the bottom portion of a liner expending tool for one in installing a motable liner in a well, while Figure 13 Libertrates the middle section of such a took and Figure 10 represents the upper sertion of the tool. The expending tool il is attached to stantoni well taking 15 by compling 15 and, typically, may be lowered from the surface through a well easing (not shown) to a point in the suring at which it is sesired to install a metallic liner. Before inserting the test into the well, an alongsted vartically accregated liner 19 fabricated from mild stand, or other sultable malashie meterial, is placed on the tool. The corrupted liner is occured in position by contact at its upper end with a cylindrical shoulder master 16 and, et the lower and by contact with a first-stage expansing die 17 in the form of a trumonted circular core stdab serves as a firstching die in the mount hareinefter described. The expanding die is fixedly edtended to a centrally located, elemented cylindrical hollow shaft ld which forms a portion of the body of the tool. As shown, the expending 4to 17 is held in place between a lower aboutder 19 and coller 21 threaded onto the short. A plurality of movehile arms 89, preservably provided with outsardly chlarged portions 85 sear the top; who disposed in the form of a sylinder around that's 18. The enlarged purbloss of the some 25 upon being moved outvarily emisse the liner to perfore the final step of expending the correlated liner into a substantially syllactrical shape. The are seahers 22 are givetally of to the shaft so as to be moveble outpurally from the shaft by a tapared expending member 26 slikebly positioned on the shelt to serve as a second-stage expander. The equience of the member 2h, as shown, moves specially along the shaft to engage with the area and more them outverbly. Advantageously, the inside surfaces of the tops 22 and the outside emface of outside seabor 25 form sating sentions, typically octogonal is shape. The expension of the arm members is controlled by the continue of the member 24 rhich moves upwardly



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writh it contains absolder 25 provided on the chaft. As member it women in a documently direction eras 22 feld invertily toward the shaft. The expending arms 22 are held in place on the shaft by collect 27 and circular grooms 20 provided on the shaft.

The expecting tool, comprising the first-stage die and the secondstage die is dress through the limit to expend it is place in the casing. The first-stage die provides a gross deformation of the kiner so that it is expended outswelly against the wall of the sessing. The second-stage die then passes through the limit and perfects the final expendion to except the inner surface of the limit and to provide more even contact between the limit and the wall of the casing and effect a finid-tight soul.

In operation, the liner setting tool is assemblat at the surface, so described shows, and a glass cloth saturated with a restance material may be so oil, is then pusped under pressure down the well inhing and flows through nameny 29 provided is galished not 51, through parts 52 and into egilader 35 commetted to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished red 31 mower appearably in cylinder 55. As shows, rot 36 cornects polished rot 31 and shaft 18 spon shigh is mounted the first-stage expending size 17. Then the piston \$4 moves appearably through the extinder 35 the expending die 17 and the secondstage die 22 ere treus speartly into the surrogated liner it and "iron out" the corregations in the liner, so that the expected liner may content the famile well of the casing in which it is being installed. Positioned to the shall below the expending menter In is a constant torce spring member IT which is employed to mye the expending number against the expending some 22 with a substantially sometant force. The force exerted against the exh methers being substantially notation, the force transmitted through the arm masters to the 30 lists and to the during will be substantially scordant so that either sticking of the tool is the casing or repture of the casing is precluded. Or course, con provided by the spring member is preselected so that the frictional

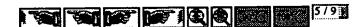


entrality of the control of the property of the property of the control of the co



forces between the tool and the liner and the presence emerted against the ensing are extended at presentanded safe levels. The constant force spring emaker examples that the contact presence between the liner femiling perturn 20 of the arms 22 is great enough to provide the torized deformation of the contact line, while preventing damage to the saming or to ble tool.

The equations force spring seasons 7 is aligned, southed on the about 15 and hald between the expending alongst 25 and a sylindrical lower choolder seasons 35 forcing a portion of a differential server alongst 39 which transmits into loading on opting number 77 to their member 15. The differential server alongst comprises shaft number 15 as the cotrible of which are not raise threads like, the lower shoulder member 15 as the cotrible of which are not raise threads like, the lower shoulder member 15 as the cotrible of threads 55 and thinkle number 1, provided with threads 11a and 11b on the cotrible and the lands, respectively, to suggest with threads of the short and the shoulder. The two cotes of threads are nowne, such as square, modified square, or done threads, to withstand very high loads and differ in prich so that shoulder 35 is seven upwartly on the short 15 when the short is revolved relative to thinkle 11. The choolder 35 is nevered to the short 15 by splines 55 so that it can alide longitudinally, but it is not true to rotate on the short. Finally arisohed to the lower and of the thinkle is a friction newher, such as her agriculty and a spline 15 and the shoulder rotation with respect to the short. Preferably, the direction of the shoulder number threads 35, is the same as that of the chart threads like, e.g. right-head threads 35, with the pitch, or lead, or threads 15a is alightly greater than these threads 35, with the pitch rotation being alone to unity. In this secure, clock-rise resolution types to the short relative to the thinkle summer, clock-rise resolution of the short relative to the thinkle summer shoulder approximately 17 to cause buckling. For example, one serior account introduce on a chart approximately 1.7-inch outside dissector and time and threads inches.



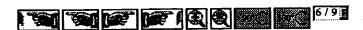


beautient force spring e)meant 31 comprises makes element by, sown-tageously committing of a plurality of alongsted solumes disputed around short 18. Opport beauting plate number the in contact with the apper ends of the solume and is elikably positioned on shall 18 to transmit the force of the approach longitudinally against the bottom and of expector sealors 30. Lower bearing plate number the contacts the lower ands of the column and is moved questily along the shall by leading the lower ands of the column and is moved to seally along the shall be lead believe a leave of lower consider 30 or a result of revolving differential server element 30. Grooves 37 sto provided in much of the bearing plates, to form an upper case and a lower case, into which the case of the column are inserted. These grooves may be shaped to contact the shape of the column much it seated. A cover 48 may be

A names for limiting the deflection of the columns to required. hithough the column element furnitions in a buckled condition, application of properly sompressive load thereto would same total failure or repture of the no. Therefore, a pair of stope k9 and 15s are provided for this purpose. on, the stope are rightly commented to the bearing plates, and, in effort comprise appear and lower limiting alasmas positioned on the sheft to 20 alide longitudinally thereon. The ends of the stops may sown toward, or may from, each other so the look on the spring number varies. Lover slaces aga ited from moding does by lawer shoulder 35 commeted to the shart 18. on the sale is much as to limit the longitudinal travel of the bearing plate members as they move together to prevent person deformation of the column element by. Textons alternative mame for preventing damage to the column element may also be employed. For example, plas or rings someted on the cheft may serve as stops, or the cover 48 provides with suitable commentations may be supliqued for tale purpose to limit longitudinal and/or lateral deflection of equame.

The columns of the column classest \$5 may be arranged erosed the graing that 18, which as shown here forces a portion of the body of the spring ferries, with each of the columns fitbed in the recess \$7. The solumns may be

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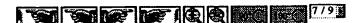


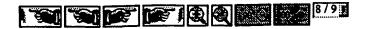


rative closely together as shore, or may be spared around the race, with separations used between them to metatain the desired spacing. The rember of construction. For example, the eleminators ratio of the column may be varied videly, sor the column mais may be recent, flat, fixed or hinged. The preserved construction is a thin, eleminated, flat, fixed or hinged. The preserved construction is a thin, eleminate column with tousded ands, from to move vithing the races shaped to the communical of the column code. Materials which may be assistated to race shaped for the columns are contain and hot alloy steels, chronium and hickel-abronium stainless steels, curious capper have allow, such as panespher bronze, beryllium support, the high stabel alloys and other similar enterials providing astisfactory technolous; properties. Typically, the individual columns are of long reconsquar cross-section, with the width bring greater than the thickness, and arranged so that the wider face of the noturns is normal to the dimester of the abert. Thus, with surficient conspression looking, the columns backle, and tend shout the said having the loars someth of inertia, e.g., outwardly may from the shaft 18.

For exemple, a group of columns D.167-inch thick by D.456-inch wife by 10.626-inches long, with the ands rounded, were fabricated from A.1.8.I byto steel, quenched and draws at 775°F. Buth columns was found to require a critical supersession loading of 560 pounds in order to beakle the enture.

After buckling, the columns were found to have a wary flot spring characteristic, as shown in Figure 3, therein Polis the critical beakling load and point 0 represents the load and deflection at which the stress is the arbsens fibers of the delaws excess the yield point of the material. Theoretically, the shape of this spring ubaracteristic curve is described by onews Od'ABC. Actually, this curve is described by OddC due to friction in the system. Foliate A and B represent typical working limits, which, af course, say he varied according to the application for which the spring is designed. For example, where a large master of flavorag system are not mutolyated, a working atrace just below the yield points may be used, while with a great number of flavorae, the working stress may be held to less than the endurance limit of the saterial of construction. In the above-marifood teats, the laters) unfaction was limited to





approximately one just, at which the longitudinal deflortes was approximately 0.225 inches. From sere defination to the section defloction, the 450-pound loading was found to be substantially constant.

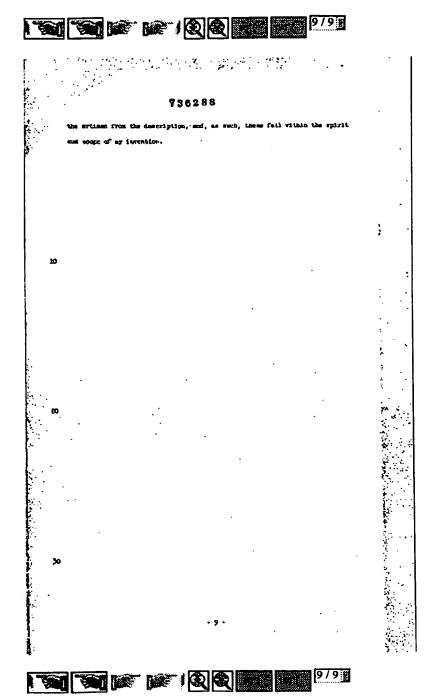
In morther tent a spring device was built, as shown, employing 80 columns, such having a critical bushing load of 1250 posses. The interal declaration was limited between 0 and about 1.00 inches by suprogrately positioning the store. Once compressional loading, the spring element bushled at substantially 85,000 possess and from a longitudinal deflection of 0.0k inshes (making) to shout 0.15 inches the load rescised substantially at 85,000 posses.

Or course, in dorigating a spring element as above it in advantageous to driven the greatest possible value of longitudinel defluction for specified values of laboral deflection and articled bubbling load, while unintening the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 18 and 2, with exhipts flat members units on safe boolumn.

In the operation of the shows expending tool for setting a liner in well entired, the medic-up tool is lowered into the rell us mestioned above, with the ares 22 in the retreated position. Shen the tool is at the desired level, the well tuining is revolved. The friction number of capages with the wall of the entired prevents thinkle by from revolving. With several revolutions of the tuining lower shoulder 15 is nevel aparently by differential entree 39 to bush a spring almost 37 which has a predeterminal critical bushing level. This level is transmitted severally against the lower on of expender 16, and the topered surface is angused with the taparent surface on the inside of the ores 21 to args the level outstantly with a substantially constant force proportional to the critical bushing loss of the spring almost. Extensionally, the expending tool is passed through the liner to expend it in the caping in the meaner described hereighedore.

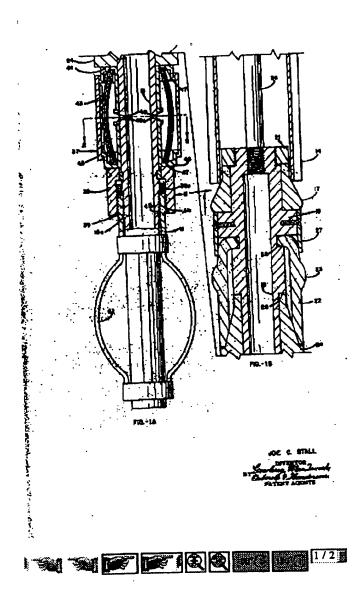
The foregoing description of a preferred emboliment of my invention has been given for the purpose of accemplification. It will be understood that verious medifications in the develop of construction will become apparent to

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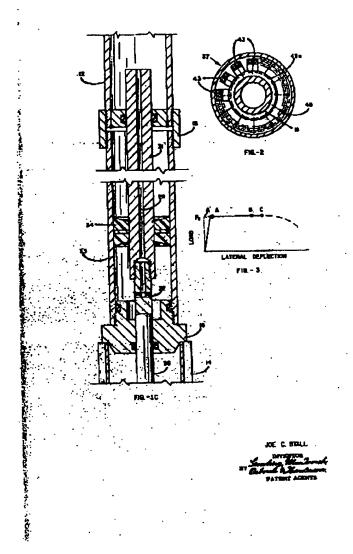




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